Volcanoes™

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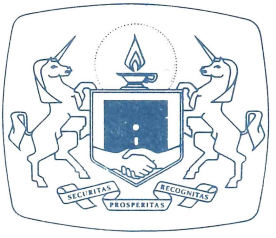

The Software Guild

SYSTEM REQUIREMENTS

Apple® II, II+ or Franklin Ace™ 1000 • 48K RAM
Applesoft • One Disk Drive • Dos 3.3

PACKAGE CONTENTS

Volcanoes Diskette
Instruction Booklet
Sample Map Sheets
Warranty Card

OVERVIEW

Will Mt. Ashfall erupt? Results of the seismic survey and infrared scan look pretty bad. As the scientist responsible for monitoring the area you debate — should we evacuate? If a blow out does occur, loss of life and property could be substantial — making Mt. St. Helens look like a dud firecracker. But then again, your reputation is on the line and a false alarm won't do it any good. There's no one to turn to — the decision is yours alone.

Volcanoes is a sophisticated game for older children and adults. Although we call it a game, the program and manual were written by a professional volcanologist, and together comprise an introductory course to volcanic processes. The various types of eruptions, volcanic rock types and modern scientific techniques for monitoring volcanoes are all covered.

IMPORTANT TIPS

Do make sure the shift lock light is lit if running this program on the Franklin Ace. This program recognizes only capital letters.

Do not press < CTRL-C> while the program is running. Results are unpredictable and damage to your program may result.

Do not open the disk drive door while the "in-use" light is on. This may damage your diskette and render it unusable.

Do not try to make a copy of this disk. Software Guild diskettes are uncopyable. If during normal use something goes wrong with your diskette, please refer to the Troubleshooting section of this manual. The Software Guild will replace your diskette as soon as possible.

Do not use a write protect tab on your Volcanoes diskette. A write protect tab prevents you from writing information on your diskette, thus preventing you from saving your games.

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Permission is hereby granted to the original purchaser of Volcanoes to reproduce the maps provided. You may also order additional sets of the maps at a cost of $5.00 (subject to change) per complete set. Please send order and payment to:

Earthware Computer Services
P.O. Box 30039
Eugene, OR 97403

Volcanoes Manual v1
October 1982
Edited by The Software Guild

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I. Introduction to Volcanoes

Welcome to the world of volcanoes. Is it a game or an education? Volcanoes is really an introductory course in volcanic processes — yet in a game format. We think you'll like it.

You can play Volcanoes without reading any of the documentation in this book. The screen messages are self-explanatory and always tell you what to do next. However, we have planned the material in this book to enhance your enjoyment of the game, and to help you become really good at predicting what the volcanoes of Wrangelia will do as you play. The game was coded by a professional volcanologist, and we hope that you will not only enjoy playing it, but also will learn something about how volcanologists study potentially active volcanoes. But it is BASICally (pun intended) a strategy game for two, three, or four players.

WARRANTY CARD

Please take a moment to complete and mail the enclosed Warranty Card. By having your name on file we will be able to provide better customer service, including information on program updates and replacement of damaged diskettes.

GETTING STARTED

To get started with Volcanoes simply follow these steps (this is called "booting"):

1. Make sure the power switch on the rear left of the computer is in the off position.

2. Open the disk drive door by pulling out and up on its bottom edge. Slip the diskette into drive #1 with your right thumb on the diskette's label. (The label will be up and will be the last edge of the diskette to enter the drive.)

3. When the diskette is entirely in the drive, close the drive door.

4. Turn the power switch to the on position. You will hear a "beep" from the computer and the "in-use" light on the disk drive will come on. This means that the program is loading.

You will now see the Softsmith logo page appear on the screen and the Volcanoes title page.

HOW TO PLAY VOLCANOES

Once you and your colleagues have "signed on," the computer will tell you, through the video monitor, what province of Wrangelia is assigned to each of you. Before playing Volcanoes you should photocopy the sample map sheets provided (both sides). Make a number of copies of each of the five maps as these will be used during play to keep track of various events. If two players are challenging the forces of volcanism, the first will need maps 1 and 2, the second will need maps 3 and 4. If three are playing, the first will need map 1, the second will need map 5, and the third will need map 4.

You will need a pencil or pen to mark the results of some of your investigations on your map(s). On the reverse sides of the maps are printed forms that will help you keep track of your work. Note that the volcanoes of Wrangelia, like real volcanoes, do not stay in exactly the same states all the time. The investigations you direct will help you get a general idea of how likely any given volcano that you study is to erupt, but a volcano could appear relatively harmless at one time and nevertheless erupt at some later time. The game has been written, however, to mimic closely the behavior of real volcanoes, and we think that the changes in probablities of eruption are "fair." Note also that one turn in the game is equivalent to three months of "game time;" this may be important, because the results of some of the investigations are influenced by the season of the (game) year. Volcanoes begins at nominal 1990 (but the game's 1990 is not simply nine years later than the copyright date!).

It is your responsibility, once you have a feeling for the chances that one or more volcanoes in an area might erupt, to adjust the warning level for that area. Any player may change any warning level during her or his turn, but before you start grinning evilly at the thought of what you will do to the other players, note that the game is coded so that poor predictions decrease the creditabilities of ALL players, although to different degrees. Good predictions can reduce damages or lives lost in eruptions by giving timely warning, and thus increase the creditabilities of all players, especially the one who is responsible for the area in which an eruption was predicted shortly before it occurred. Your budget depends in part on your public and scientific creditabilities, and in part on tax bases of the areas for which you are responsible. Tax bases grow with time but are diminished if damaging eruptions occur, so that it is important to you to make good predictions, for several reasons. Just as the case in real life, in this game you must cooperate to understand natural phenomena and to limit the damaging effects of dangerous natural processes. The game has elements of competitiveness among players, of course, but these are less prominent than in many strategy games.

You may leave the game cleanly after any volcanic eruption. When you do so, you may save the variables of the game in files on the diskette, so you can return to exactly that game when you wish. If you return to the same game several times, or save game variables every now and then under different names, you can branch in game space-time to try "what if" alternatives, but be warned — the diskette is pretty well stuffed full, and you can't save many different sets of game variables.

II. Volcanoes and Volcanoes — Game and Science

GENERAL HISTORICAL BACKGROUND

Almirante Perulera, commanding a squadron of three ships and ordered by the Spanish government to search for a Northwest Passage, first sighted several of the volcanoes of the Wrangelia region in August of 1786. He named Mt. Asuncion, Boca Cerrada Peak, and Mt. Fuego (which was erupting when first sighted) of the archipelago now named for Captain Afringham of H.M.S. Astrolabe, who made landfall there in July 1788. Perulera also named El Matador on the mainland, from a fancied resemblence of that cinder cone and the shield volcano of Rift Mtn. (originally named El Toro) to a bullfighter and bull. He (or rather, his lookouts; the Almirante is thought to have been near-sighted) must have seen many other volcanic edifices of the region, but there is no mention of them in the expedition's logbooks (preserved in archives at Barcelona).

Perulera's ships anchored just outside Dog Leg Harbour, between George Is. and Charlotte Is., to take on water, firewood, and whatever food could be obtained (chiefly smoked salmon and dried berries, according to logbook entries) by trade with the local inhabitants. From later writings by Sr. Eduardo Churruca, aboard as a volunteer (?) naturalist, it is clear that at least one small party from the ships climbed the northern slopes of Mt. Fuego to the rim of the summit caldera, and observed fire fountains and lava flows erupting from the South Rift Zone. Churruca describes how the tongues of lava divided as they flowed around the base of what we now know as Rolling Stone Butte; his description allows us to identify confidently the products of the 1786 eruption, even though Mt. Fuego has erupted quite frequently since then.

The Perulera expedition put out to sea rather hurriedly, apparently because they were alarmed by signs of an impending eruption of Mt. Asuncion. (The logbook does not state clearly where the alarming symptoms originated, but because Perulera's ships had not fully replenished their essential stores, it seems likely that the volcano showing signs of activity was thought to be potentially more dangerous than was Mt. Fuego. Perulera did not discover the splendid anchorage of Georgeville Harbour, and certainly his ships would have been seriously threatened by even a moderate eruption of the Asuncion volcano, if the wind had shifted towards a more northerly bearing.)

When Afringham sighted the archipelago that now bears his name not quite two years later, Mt. Fuego was quiet but Asuncion was emitting minor steam bursts and ash-laden blasts, and a very fresh-looking lava flow (exhibiting an alignment of steam vents, apparently where it had overriden a small stream valley, on which Afringham commented at some length in his logbook) was seen on Asuncion's southeastern slopes. No such lava flow was mentioned by Perulera, but the omission may not be significant. On the whole it seems likely that Asuncion did indeed erupt a lava flow between August of 1786 and July of 1788; this lava seems to have been buried by products of more recent eruptions of the volcano.

Afringham found and was much taken with Georgeville Harbour, although his enthusiasm for it was somewhat tempered by the light shower of volcanic ash from Mt. Ashfall (named by Afringham in honor of the occasion) that was carried by an east wind to sprinkle the rigging and deck of his ship during 21st to 23rd July, 1788. (This wind direction is unusual; west winds prevail in Wrangelia during most of the year.) Afringham recognized the potential hazards of eruptions from Asuncion and Ashfall, but seems to have been unaware that Georgeville Harbour itself was formed by lavas from the Deadfall Butte cinder cone, and could be closed off in some future eruption by such a lava. His report emphasized the advantages of the harborage and the abundance of natural resources such as fish, furs, and timber far more than the volcanic hazards, and was instrumental in encouraging the first European settlement, at Georgeville in 1801.

Although many ships visited the archipelago and the coastal areas of the adjacent mainland during the early 1800's, and there were permanent European settlements at Georgeville and Camas Marsh (later re-named Camasport), we have regrettably little information about volcanic activity during the first part of the nineteenth century, perhaps because it was so common as to be unremarkable. We know of an eruption of wide-spread air-fall ash from Boca Cerrada during the winter of 1815, and there are somewhat confusing reports of what probably was an ash-flow tuff (ignimbrite) erupted from Cumulus Peak that destroyed good furtrapping grounds northwest of that volcano during the summer of 1823. Reconnaissance geologic mapping of coastal Brigalorn suggests that a tongue of this ash flow may have moved down the Talogit River Valley nearly to the present site of Talogit City, but the precise date of eruption of this ignimbrite has not been determined.

Until the 1860's, the areas east of the Cumulus Peak — Skyline Peak — Mt. Ashfall axis were very sparsely settled. Beginning in that decade transcontinental migration and the growth of agricultural settlements along the rivers of Interior Derkin changed that general area from a largely-ignored hinterland to one of considerable economic importance. This process was greatly accelerated by discovery of placer gold deposits east of the city of Salmon Creek, which grew rapidly as a consequence. Salmon Creek now is a mining, lumbering, and manufacturing center rivalling the older communities of Georgeville (fishing, textiles, manufacturing, and shipping) and Camasport (manufacturing, shipbuilding and shipping, wood products, electronics). Four smaller cities are located in the region. Arbol Creek, at the south end of Prince Ernest Is., depends on fishing, papermills, and lumber. Talogit City, across Afringham Passage to the east of Arbol Creek, ships food products, building stone, and lumber. Wolfridge at the confluence of Thunder River and the South Fork of Camas River, about 35 kilometres NNE of Cumulus Peak, is known for forest products, tourism, a major wildlife park, and outdoor recreation. Indian Ford on the north bank of the main stem of Camas River, about 40 kilometres SW of Mt. Ashfall, specializes in manufacturing, food processing, and dairy products and their distribution, and is a transportation hub.

The small towns in Afringham are Dog Leg Harbour and Driftwood (Charlotte Is.) and Emily (Prince Ernest Is.). Ratchetville is located in coastal Brigalorn, just west of Ratchet Mt., and Deertrail is in interior Brigalorn, about 34 kilometres east of Cumulus Peak. In Camasport (the name both of one of the principal cities of Wrangelia and of the province in which that city is located), Black Sands Beach is on the coast, just north of the Rift Mtn. shield volcano, and Slide is about 28 kilometres east of the city of Camasport. Small towns of Derkin are Otter Rock and Seal City (south and north, respectively, of the Derkin River in coastal Derkin) and Green tree, along the upper Camas River about 40 kilometres SSW of Salmon Creek.

VOLCANOLOGY

The major volcanoes of Wrangelia have been classified, somewhat arbitrarily, into three types: andesitic composite volcanoes, basaltic shield volcanoes, and cinder cones. The five andesitic volcanoes are much like those found at and near continental margins around the Pacific, except they seem to erupt more frequently than is commonly observed elsewhere. Reconnaissance studies have shown that they tend to erupt pyroclastic material (air-fall ash tuff blankets and ash-flow tuffs) more frequently than lavas, although this conclusion may be wrong because the lavas tend to be restricted to the slopes of the volcanoes, and the tuffs are typically widespread. (These volcanoes are called "composite" because they are composed of nearly equal amounts of lavas and of fragmental materials like tuffs and lahars, but of course we do not know, even roughly, what the proportions of these eruption products are in any composite cone because the youngest materials veneer and hide the older ones, and all the cones have been eroded only to a minor degree.)

Three basaltic shield volcanoes (one in the Afringham archipelago — for which a better term might be the "Afringham island arc" — and two that are part of the mainland coastal belt of volcanic vents) in the region erupt frequently, sometimes from rift zones that cut these volcanic edifices, sometimes from the summit caldera found in each. Eruptions from vents at or near the summit tend to precede those from rift zones, much as has been very well documented for Hawaiian shield volcanoes in their youthful stages of development. Fire fountaining is common, especially during early stages of summit eruptions and often spectacular but rarely hazardous. Lavas, especially those erupted from rift zones low on the flanks of the shields, tend to cause most of the damage and the rare injuries associated with this style of volcanism.

Although the andesitic composite cones and the basaltic shield volcanoes of this region are in many ways quite similar to their counterparts elsewhere, some at least of the cinder cones of this region appear to be unusual. In general, it is rare to observe multiple eruptions, separated by quiescent periods of many years, from cinder cones. They tend, rather, to erupt during a fairly short time-span, building the entire edifice (a cinder cone, sometimes with a lava flow breaking out of its base late in the eruptive cycle) and then becoming extinct. Fragmentary evidence (e.g., see outlines of eruption histories for Deadfall Butte, Moss Mtn., and Rolling Stone Butte) suggests that at least some of the cinder cones of this region have erupted repeatedly. It is probably prudent to consider all of them as dormant unless detailed studies of individual cinder cones suggest that they are indeed extinct. Perhaps some of the region's cinder cones are in reality very youthful composite volcanoes, that simply have not yet grown to sizes that would make it easy for us to recognize them as such.

Volcanic eruptions in the region since 1875 have been reasonably well-documented; summaries of the historic records of these eruptions, 1875 to 1990 (with comments about earlier eruptions, if records exist), are given below, following tabulations that will help you to keep in mind the names and locations of the volcanoes.

TABLE 1: Names and Locations of Volcanoes, Grouped by Type

Andesitic Composite Volcanoes

Code	Name	Location
A1	Mt. Asuncion	George Is., Afringham
A2	Boca Cerrada Peak	Prince Ernest Is., Afringham
A3	Cumulus Peak	Interior Brigalorn
A4	Skyline Peak	Border of interior Camasport and southern interior Derkin
A5	Mt. Ashfall	Northern interior Derkin

Basaltic Shield Volcanoes

Code No.	Name	Location
B1	Mt. Fuego	Charlotte Is., Afringham
B2	Rift Mtn.	Coastal Camasport
B3	Flat Top Mtn.	Coastal Derkin

Cinder Cones

Code No.	Name	Location
C1	Deadfall Butte	Northern George Is., Afringham
C2	Rolling Stone Butte	Central Charlotte Is., Afringham
C3	Moss Mtn.	Southern Charlotte Is., Afringham
C4	Dogwood Mtn.	Northern Prince Ernest Is., Afringham
C5	Ratchet Mtn.	Northern coastal Brigalorn
C6	Rumble Butte	Central costal Brigalorn
C7	Bear Claw Butte	Northern interior Brigalorn
C8	Salt Lick Mtn.	Southeastern interior Brigalorn
C9	Broken Thumb Butte	Northern coastal Camasport
C10	El Matador	Central coastal Camasport
C11	Bubbling Springs Mtn.	Northern interior Camasport
C12	Broken Fish Mtn.	Central interior Camasport
C13	Forked Tongue Butte	Central coastal Derkin
C14	Dyke Butte	Southern coastal Derkin
C15	Conejo Mtn.	Central northeastern Derkin
C16	Twisted Trunk Mtn.	Southwestern part of NE Derkin
C17	Whisper Butte	Southeastern Derkin

For your convenience, here is a list of volcanoes in alphabetical order (prefixes of "Mt." were ignored in putting this list into sequence):

TABLE 2: Alphabetical Listing of Volcanoes

Mt. Ashfall	A5	Northeastern Derkin
Mt. Asuncion	A1	George Is., Afringham
Bear Claw Butte	C7	Northern Interior Brigalorn
Boca Cerrada Peak	A2	Prince Ernest Is., Afringham
Broken Fish Mtn.	C12	Central interior Camasport
Broken Thumb Butte	C9	Northern coastal Camasport
Bubbling Springs Mtn.	C11	Northern interior Camasport
Conejo Mtn.	C15	Central northeastern Derkin
Cumulus Peak	A3	Interior Brigalorn
Deadfall Butte	C1	Northern George Is., Afringham
Dogwood Mtn.	C4	Northern Prince Ernest Is., Afringham
Dyke Butte	C14	Southern coastal Derkin
El Matador	C10	Central coastal Camasport
Flat Top Mtn.	B3	Coastal Derkin
Forked Tongue Butte	C13	Central coastal Derkin
Mt. Fuego	B1	Charlotte Is., Afringham
Moss Mtn.	C3	Southern Charlotte Is., Afringham
Ratchet Mtn.	C5	Northern coastal Brigalorn
Rift Mtn.	B2	Coastal Camasport
Rolling Stone Butte	C2	Central Charlotte Is, Afringham
Rumble Butte	C6	Central coastal Brigalorn
Salt Lick Mtn.	C8	Southeastern interior Brigalorn
Skyline Peak	A4	Between Camasport and Derkin
Twisted Trunk Mtn.	C16	Southwestern part of NE Derkin
Whisper Butte	C17	Southeastern Derkin

Here is a list of volcanoes according to provinces and areas within the provinces. (Note the codes used to identify the areas, for future reference.)

TABLE 3: Volcanoes Grouped by Location

AFRINGHAM		
Area 1	George Island	Mt. Asuncion
		Deadfall Butte
Area 2	Charlotte Island	Mt. Fuego
		Rolling Stone Butte
		Moss Mtn.
Area 3	Prince Ernest Island	Boca Cerrada Peak
		Dogwood Mtn.
BRIGALORN		
Area 4	Coastal Brigalorn	Ratchet Mtn.
		Rumble Butte
Area 5	Interior Brigalorn	Cumulus Peak
		Bear Claw Butte
		Salt Lick Mtn.
CAMASPORT		
Area 6	Coastal Camasport	Rift Mtn.
		Broken Thumb Mtn.
		El Matador
Area 7	Interior Camasport	Skyline Peak
(**Note:** responsibility for monitoring Skyline Peak is shared among the volcanologists in charge of investigations in Camasport and in Derkin.)		
		Bubbling Springs Mtn.
		Broken Fish Mtn.
Area 8	Coastal Derkin	Flat Top Mtn.
		Forked Tongue Butte
		Dyke Butte
Area 9	Northeastern Derkin	Mt. Ashfall
		Conejo Mtn.
		Twisted Trunk Mtn.
Area 10	Southeastern Derkin	Skyline Peak
(**Note:** responsibility shared as noted above.)		
		Whisper Butte

SUMMARIES OF RECORDS OF VOLCANIC ERUPTIONS (pre-1990)

Mt. Asuncion (A1) probably erupted a lava flow during the period 1786 to 1788. Between about 1790 and 1820 it erupted four ignimbrites and at least six air-fall ash tuff blankets. It may have erupted a lava in 1855; it erupted a large air-fall ash, accompanied by a lahar and causing 48 deaths and much damage in Georgeville, during 1872. Asuncion erupted an ignimbrite (minor damage to forests) in 1935; dormant from 1942 to 1990.

Boca Cerrada Peak (A2) erupted extensive air-fall ash in 1815, and again in 1882, 1902, and 1915. Ignimbrites erupted in 1895, 1901, and 1913. Minor eruptions since 1915; dormant from 1927 to 1990.

Cumulus Peak's (A3) eruptive history is poorly known; probable ruption of an ignimbrite in 1823. Air-fall ash erupted in 1920, 1935, 1942; ignimbrite in 1925. It has been dormant from 1945 to 1990.

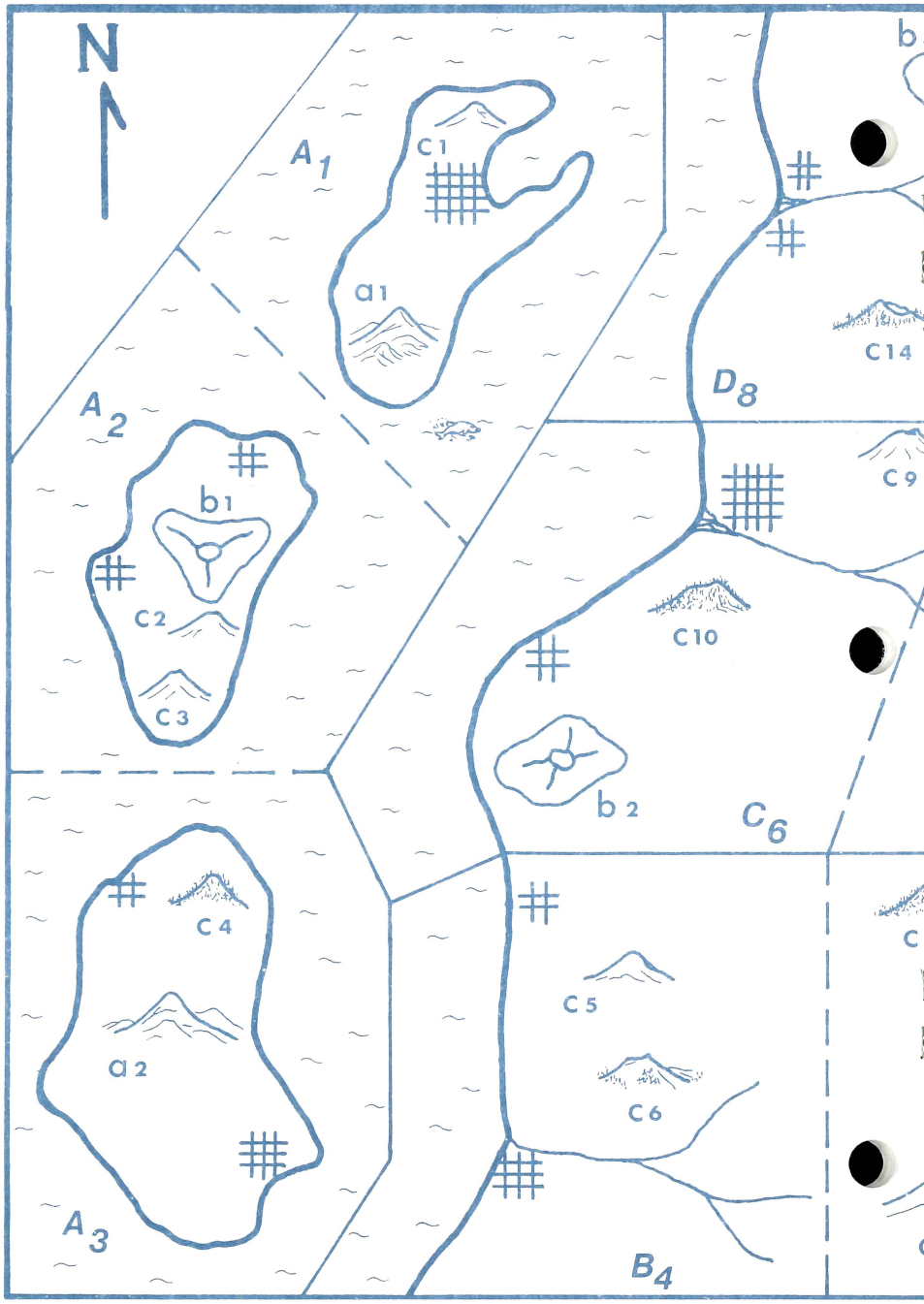
Skyline Peak's (A4) eruptive history is very poorly known; even since 1875 eruptions from it and from nearby cinder cones have not been reliably distinguished. It may have erupted as many as ten times between 1900 and 1975. It erupted an ignimbrite in 1984, with heavy damage to forests northeast of the Peak.

Mt. Ashfall (A5) was named after a large eruption in 1788. At least thirteen eruptions of ash (the dates of which are very poorly known) were seen from Georgeville between 1805 and 1875; additonal eruptions are recorded for 1901, 1919, 1926, and 1936. Ashfall's history of eruptions of ignimbrites, lahars, and lavas is unknown. It has been dormant from 1936 to 1990.

Mt. Fuego (B1) erupted lava and vent agglomerate (from a remarkable fire fountain) in 1786, and at least five lavas between ten and 1890. Lava erupted in 1902, 1907, 1910, 1912, 1928, 1933, 1934, 1938, 1941, 1962, 1963, 1967, 1982, and 1985.

Rift Mtn. (B2) erupted lava at least three or four times between 1832 and 1860. Lava erupted in 1885, 1887, 1894, 1915, 1922, 1924, 1943, 1945, 1952, 1959, 1964, 1981, 1987.

Flat Top Mtn.'s (B3) fifteen lava eruptions between 1804 (when lava was seen at the Western Rift Zone) and 1913 were observed from Georgeville, but except for the 1804 and 1902 events, exact dates are not known. Eruptions from the Eastern Rift Zone prior to 1940 may have gone unnoticed. Lava erupted in 1917, 1920, 1945, and 1976. Dormant from 1976 to 1990.


N
A1
A2
A3
B4
C6
D8
a1
a2
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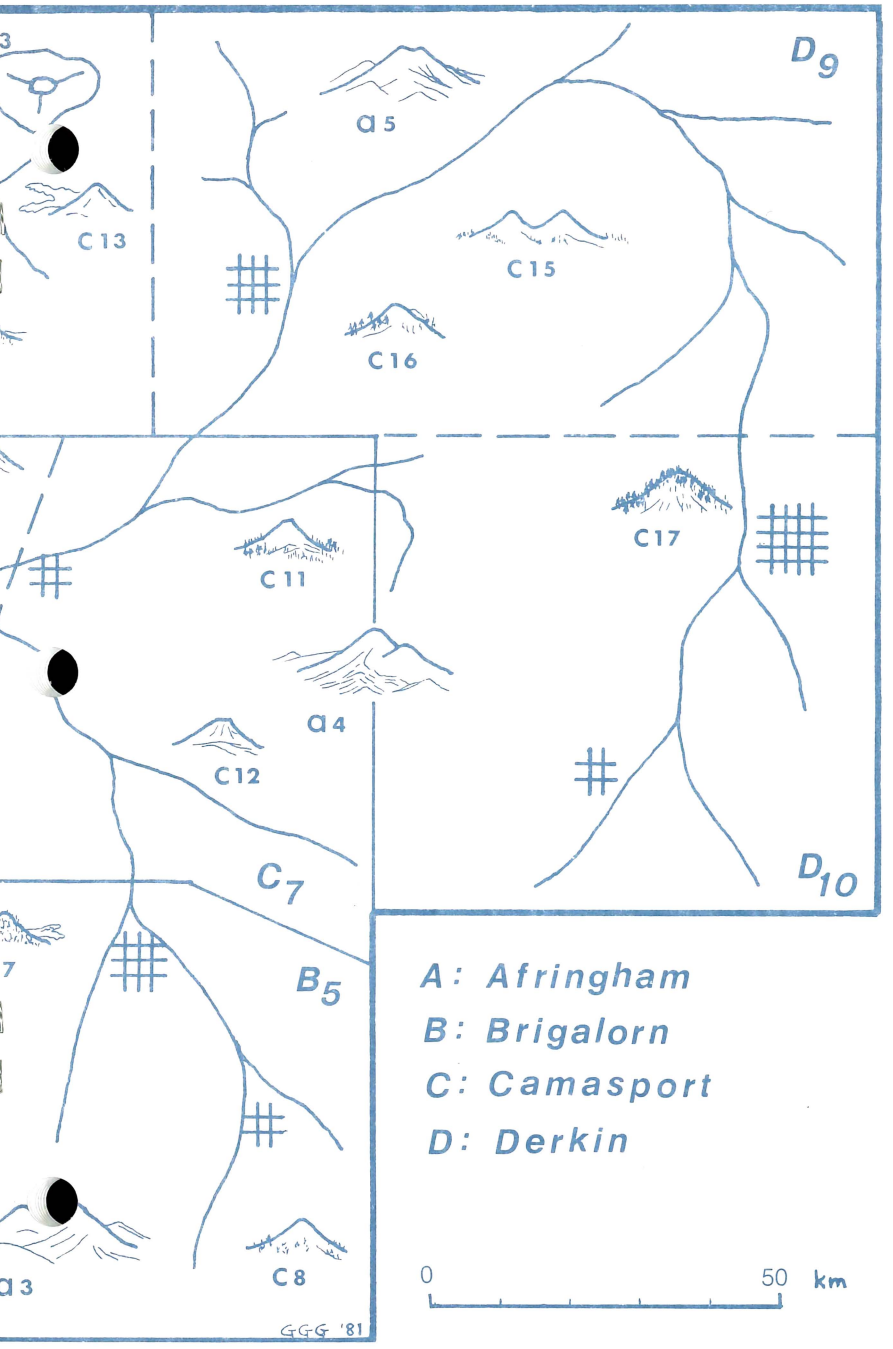
C3
C4
C5
C6
C9
C10
C14


D9
a5
C15
C16
C13
C11
C17
a4
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a3
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A: Afringham
B: Brigalorn
C: Camasport
D: Derkin
0
50 km

Deadfall Butte (C1) erupted air-fall ash in 1803, 1814, 1816, 1821 (seven lives lost, many injured), 1825, 1891, 1893, 1894, 1930, 1931, and 1936. It erupted lava in 1817, 1823, 1895, 1896, 1933, and 1934, but has been dormant from 1936 to 1990.

Rolling Stone Butte (C2) like its neighbor Moss Mtn., is hidden from the Georgeville area by Mt. Fuego, and often hidden from Camasport by persistent fog in Afringham Passage. Many eruptions prior to 1945 may have gone unnoticed. Ash erupted in 1933 and again in 1942; a series of four ash eruptions, terminated by a lava flow, occurred during the period 1972 to 1980 and was studied with some care. Dormant from 1980 to 1990.

Moss Mtn. (C3), like Rolling Stone, is difficult to observe and many eruptions prior to 1945 may have gone unnoticed. Lava flows erupted in 1925 and 1962; air-fall ash in 1958, 1959, 1963, and 1966. Dormant from 1966 to 1990.

Dogwood Mtn. (C4) is named after a common tree in the thick forest covering it; no known eruptions.

Ratchet Mtn. (C5), despite its location in a zone of heavy rainfall, is lightly vegetated and may therefore have erupted vigorously within the past few hundreds of years. No known eruptions.

Rumble Butte (C6) is moderately-well vegetated; no known eruptions.

Bear Claw Butte (C7) is heavily forested, except on the surfaces of a prehistoric lava flow that issued from the northeast part of its base. No known eruptions.

Salt Lick Mtn. (C8) sits on metamorphic rocks and relatively old sedimentary rocks; it is lightly vegetated, but has no history of known eruptions.

Broken Thumb Butte (C9) erupted lava in 1822 and airfall ash in 1818 and 1825. Minor steam blasts were observed 1962 and 1963. Dormant from 1963 to 1990.

El Matador (C10) is heavily vegetated and presumably has not erupted for at least several hundred years.

The only indications of volcanic activity at Bubbling Springs Mtn. (C11) are the hot springs near its base for which this volcano is named. It is lightly vegetated and may have erupted during the period 1887 to 1911.

Broken Fish Mtn. (C12) must have erupted at least two air-fall ash blankets and one lava flow since 1875, when it was described in a trapper's journal as heavily forested (it is now essentially unvegetated). Dates of these eruptions are not known; dormant from at least 1923 to 1990.

Forked Tongue Butte (C13) is named after the "forked" lava flow that issued from its base on the NW side. This lava covers ash that is probably from the Mt. Ashfall eruption of 1788, but could be younger; it is itself overlain by three distinguishable air-fall layers, from unknown sources. Dormant from at least 1911 to 1990.

Dyke Butte (C14) is named after two sets of prominent radiating dikes, exposed by erosion on its N and NE sides. The cinder cone appears to have been dormant for some hundreds of years or more.

Conejo Mtn. (C15) consists of twin peaks, thought to resemble rabbit ears and joined by a saddle of moderate elevation. Conejo is a large edifice with no history of eruptions, but is perceptibly less heavily vegetated than its neighbor, Twisted Trunk Mtn.

Twisted Trunk Mtn. (C16) stands at a relatively high elevation where regrowth of plant cover after eruptions is slow, yet it seems to be about as well vegetated as are neighboring areas. No known eruptions.

Whisper Butte (C17) is covered with a pine forest, including some trees that must be many hundreds of years old. It is an exceptionally large cinder cone. No known eruptions.

GLOSSARY

ANDESITIC VOLCANO: A volcano built principally of andesite, an igneous rock with composition between basalt (poor in silica) and rhyolite (silica-rich). Andesites occur as lava flows and as pyroclastic materials (such as volcanic ash) erupted from volcanoes that are usually located near the edges of continents.

ASH: A fine-grained material formed as a result of volcanic explosions. This material may be erupted high into and then fall from the air to form a bedded sediment on the ground, or it may be deposited from a seething turbulent ash flow that moves close to the ground. In the latter case, the ash deposit usually lacks prominent bedding (it is unstratified) and can retain enough heat so that the fragments weld together after it is deposited, to form an ignimbrite (welded ash-flow tuff).

BASALT: A fine-grained, sometimes glassy, basic (silica-poor, iron- and magnesium-rich) igneous rock. Basalts are generally associated with oceanic volcanism, as opposed to the andesites which are associated with the margins of continents. Basalts are thought to have formed as partial melts deep within the bowels of the Earth.

CALDERA: A large crater, which may form in several ways, the most common of which is collapse during a large volcanic eruption.

CINDER CONE: A conical hill or small mountain, often with a truncated top in which is a bowl-shaped crater. It forms by deposition of cinders around a more-or-less circular vent during moderately explosive eruptions. Lava may erupt from the central crater or may break out at the base.

EPI-CENTER: The point on Earth's surface directly above the focus of an earthquake (the focus of an earthquake is the zone within the Earth in which rocks break and shift to cause the quake).

ERUPTION: A volcanic event which is the direct result of movement of magma (molten rock) beneath Earth's crust.

FIRE FOUNTAINING: Streams of lava shot skyward from a vent (usually an elongated vent called a fissure) owing to the force of expanding gases that are being released from the magma as it approaches the surface.

IGNIMBRITES: Rocks formed by the welding or sticking together of still-plastic bits of glass and pumice in deposits of hot fragmental material. Flows which produce these deposits are called ash flows, and an alternative name for ignimbrite is welded ash-flow tuff. Ash-flow tuffs need not be welded, however, if they were deposited while cool. Deposits from mud flows, called lahars, sometimes have features like those of ignimbrites. All these kinds of fragmental flows can be very destructive.

ISLAND ARCS: Volcanic islands, generally in arcuate rows, major features of which are chains of andesitic volcanoes.

LAHARS: Fragmental deposits formed from mud-flows that sweep rapidly down volcanic slopes, usually more-or-less confined to stream valleys draining the volcanic edifice. Lahars often are directly associated with an eruption (e.g., the mud flow and lahar of the great eruption of Mt. St. Helens on 18 May 1980), but sometimes form when overly-steep volcanic slopes lubricated by rain or melting ice break loose in the absence of eruptive activity.

LAVA: Molten rock (generally containing dissolved gases) which issues from Earth's interior onto the surface of the Earth.

PYROCLASTIC: Materials thrown out by a volcano in a fragmentary form, either a solid or a liquid, are called "fire broken" or pyroclastic.

RIFT ZONES: Elongated areas of fissures, formed where rocks are affected by stretching of Earth's crust, which serve as channelways to bring magma to the surface.

SEISMOGRAPH: An instrument designed to measure the movement of the ground during an earthquake. Modern seismographs telemeter their results to a central location where the data are analyzed to find out what kind of earthquake has been observed, and where it originated.

SEISMOGRAM: A record of the different kinds of waves that occur in an earthquake. Each type of wave moves through the Earth in a different way, and conveys different information about the materials through which it moves.

SHIELD VOLCANO: Through the repeated outpourings of fluid lava around a vent, a cone can be constructed. In shield volcanoes, these cones have a low, broad profile with a small crater or caldera in the top. However, if the viscosity of the lava erupted increases, or if cinders are erupted, a small steeper-sided central cone develops, so that the volcano looks like a hugh Viking shield laid on the ground (shield volcanoes were given that name in Iceland).

TUFF: Ash deposits which are consolidated and in which the fragments are no larger than 2 cm. in diameter.

INFORMATION ON INVESTIGATIONS

HV: History of Volcanic Eruptions (after 1990)

Your computer keeps track of all volcanic eruptions reported in Wrangelia after 1990. (For information on what is known about eruptions before 1990, when you took charge of your research team, see the SUMMARIES ... section above.) You can call up these records, to remind yourself and your colleagues about which volcanoes have been active recently, and how dangerous they have been. A shield volcano that has erupted recently is moderately likely to erupt again in the near future. There may be either a series of closely-timed eruptions from the other kinds of volcanoes, or one or two eruptions followed by long periods of quiescence.

IR: Infrared Scan of an Area

Aim: To find "hot spots" in an area that may indicate volcanic hazards.

Background: If magma has been stored in a shallow chamber for a few years or more, the heat flowing from the magma into the surrounding rock can act to raise the temperatures of the rocks and soils at the Earth's surface near the magma chamber. These elevated temperatures can be detected by a variety of types of measurements (placing your hand on the ground to test if it feels warm is NOT one of them!) However, you should note that if a magma chamber is deep, or small, or young, or if lots of groundwater is flowing over the top of it and carries away its heat, it might not be detected even by a very careful survey of surface temperatures. Also, human activites of many different kinds produce heat, and if you are not careful about your interpretations you could mis-identify "hot spots" that result from human activities as signatures of magma chambers.

Method: Space satellites that are instrumented to survey earth resources, and specifically to examine the Earth's surface in infrared light (the wavelengths of light that are longer than those we can detect with our eyes, and are profusely emitted by warm or hot objects), pass over Wrangelia and are available for your use. However, the sensors on those satellites are not well suited to penetrate cloud cover, which is very common in western Wrangelia during the winter and parts of the autumn and spring. An alternative is to use infrared sensors mounted on airplanes, if the satellite images are not available (or just to wait for the weather to clear.) In either case, the data on intensities of infrared light that were recorded by the instruments you chose to use will be "massaged" by a computer, and the locations of "hot spots," if any are found, will be reported to you. You must then interpret that information.

SS: Seismic Survey of a Volcano

Aim: To look for volcanic tremor or other evidence of impending volcanic activity.

Background: Seismic signals are waves traveling through the Earth that are produced by natural events. They include but are not limited to waves from earthquakes. A particular kind of seismic signal that is important in studying volcanoes is "volcanic tremor," the fairly regular vibrations caused by magma moving through volcanic "plumbing systems". (In a sense, volcanoes often hum to themselves when they are pumping their working fluid (magma) from one place to another. The humming is in some ways similar to tones produced by a wind instrument, such as an organ or a flute, although of course the working fluid air in one case, molten rock in the other — is very different.) Movement of magma within a volcano precedes almost all eruptions although magma can move and then simply stay within the volcano, rather than erupting.

Local seisms, usually caused by small earthquakes within or near the volcanic edifice, also can be symptoms of internal readjustments that may precede eruptions. In typical local seisms, a burst of energy signals the arrival of the seismic waves at the seismometer, and the intensity of the waves then dies away fairly smoothly. This is because, although there are different kinds of seismic waves that travel at different velocities, when they are generated close to the seismometer that detects them, the waves have not traveled far enough to sort themselves out according to their velocities. In volcanic regions, most local seisms are too weak to be detected at any substantial distance from their sources, so that if your seismometers record local seisms, you can be fairly certain that they originated in or near the particular volcano you are studying. Teleseisms (those that have traveled a long way) will show a pair of distinct first arrivals, initially of the "primary wave" (which travels faster), then of the "secondary wave". They are likely to appear in your seismic records, but do not help you to predict volcanic activity in your areas.

Method: You have available to you a number of seismometers that can be set up to operate remotely, recording seismic events and telemetering by radio their records when they are directed to do so by a central data-processing installation. They are relatively light-weight (no seismometer is really "light-weight," because the part of it that actually records wave motion must be massive enough to resist moving easily, through its inertia, when the ground begins trembling under it), and can be set up almost anywhere on the slopes of a volcano. The computer that processes the data will report to you the average number of seismic events with intensities (Richter magnitudes) greater than three recorded per month, and will show you a selection of typical seismic records for you to examine and interpret. Note that if you choose to put lots of seismometers on a particular volcano, you will almost certainly detect more events than if you had put fewer instruments in the field. Thus, the number of fairly-energetic events, although it is partly dependent on the internal state of the volcano, is also partly dependent on the way you did this investigation. The presence or absence of volcanic tremor, or of local seisms, among the events observed should be a useful guide to the chances of an eruption from that volcano occurring in the near future, although as noted above, magma can be moving around with a volcano and the volcano can be generating local seisms, but never erupt. Use your judgement.

EC: Electrical Conductivity near a Volcano

Aim: To detect zones of unusual electrical conductivity, which may indicate the existence of shallow magma chambers.

Background: Most rocks are good electrical insulators (or poor electrical conductors, which is just another way of saying the same thing). However, there are some earth materials that exhibit unusually large conductivities. They include: 1) ore minerals of many kinds, and 2) magma (which conducts electricity far better than do common rocks). Thus, if one can measure electrical conductivity on a broad scale, it becomes possible to search for either economically-minable ore bodies or for shallow magma chambers. It is difficult to find deep magma chambers with this kind of survey, because the conductivity anomalies they cause tend to merge into anomalies formed in other ways, but if (as is the case for most of Wrangelia) you can be fairly sure that ore bodies are not common enough in the area surveyed to confuse the picture, it is a good approach to detecting shallow magma chambers.

Method: One of the most useful methods of determining electrical conductivity on an appropriate scale is to lay out a loop of thick electrical cable, put an electrical pulse through it which generates a strong magnetic pulse, and observe in detail how that magnetic pulse interacts with the Earth. Field magnetometers are fairly cheap and easy to carry around, and it is best to set up the loop and the electrical generator (usually truck-mounted) in one location near the center of the area you want to survey, then to move the magnetometers around, stopping at a number of locations and recording the results of transmitting a series of magnetic pulses. A small computer is usually set up in the truck, along with the rest of the equipment that is required, and chews on the data as they are radioed in from each of the magnetometer stations in turn. With this approach, your survey team can build up a model of the electrical conductivity anomalies as they are working, and when they decide they have been away from town long enough, and have enough data to impress you with how good a job they have done, they can pull stakes (really, pick up the big loop of wire).

You will get a report of where conductivity anomalies have been found. You must then interpret those anomalies (or their absence), keeping in mind that not every volcano with a shallow magma chamber will necessarily erupt in the near future, and that volcanoes may erupt by drawing magma from deep sources, that you cannot detect with this kind of investigation.

TS: Tiltmeter Survey of a Volcano

Aim: To find patterns of short-term swelling or deflation of a volcano, which help predict eruptions.

Background: If magma is added to or withdrawn from shallow magma chambers, the ground surface above the chamber swells or deflates. Many volcanoes have magma chambers within or just below the pile of erupted material that forms their visible structure. Magma flowing into such chambers from deeper sources just before an eruption will cause the volcano to swell, and magma moving through a "plumbing system" from one chamber to another will cause deflation of one part and inflation of another part of the volcano. For instance, in a Hawaiian-type shield volcano magma transfer from beneath the central caldera to a rift zone can be tracked by measuring the shape of the volcano, and such measurements help to predict when magma might begin erupting from fissures in the rift zone. But don't be fooled — volcanoes do not always swell measurably before eruptions; volcanoes drawing on deep magma reservoirs usually erupt without noticeable swelling.

Sometimes the swelling can give a very detailed picture of magma movement. An example is the swelling of the north side of Mt. St. Helens during March, April, and May of 1980, because a shallow intrusive dome was forming beneath the surface. Sliding of the rock masses above that dome off the flank of the volcano triggered the destructive eruption of 18 May 1980.

Method: Volcanic deformation used to be measured by establishing baselines like the ones that surveyors use, then remeasuring them every few days. Prowling around on the flanks of active volcanoes with surveyor's transits made geologists' spouses and insurance agents unhappy, so tiltmeters were invented. A tiltmeter measures the tilt of the ground it is standing on, usually by bouncing a lasar beam off a precisely-located distant reflector, and telemeters by radio a record of ground tilting to a central receiving station. These records are then analysed by a computer, to provide a picture of how the volcano is deforming. Once a tiltmeter is installed (often by geologists in a helicopter, so they can leave in a hurry if necessary), it generally requires no further attention for many months. Of course, a large eruption can destroy many or most of the tiltmeters on a volcano, and if it seems that the volcano will continue to be active, they should then be replaced. It may, under certain circumstances, be difficult to find volunteers to go back to replace damaged or missing tiltmeters. If you are unable to locate volunteers, you probably don't need tiltmeters to to tell you that something dramatic is going on!

GA: Analyses of Gases Emitted by a Volcano

Aim: To use compositions of volcanic gases as guides to the chance that the volcano will erupt.

Background: Dormant and active volcanoes emit gases with compositions that can be very different from that of the atmosphere. These gases are usually mainly steam, from water percolating through the porous rocks typical of most volcanoes that is heated and escapes in fumaroles or steam vents. But if substantial quantities of magma are present close to the vents from which the gases are escaping, then the gases can be quite rich in other components. Important magmatic gas components include carbon dioxide and especially sulfur dioxide. If the gases have reacted chemically at high temperatures, with not much reaction at lower temperatures to obscure the high-temperature imprint, hydrogen and carbon monoxide may be present in considerable amounts. Thus, both the proportions of the various compounds in the volcanic gases, and their amounts (usually expressed as tons per day, and calculated from the composition of a small sample or two and an estimate of the total flow rate), may be useful in predicting volcanic activity.

Method: In order to sample volcanic gases, you (or, more likely, some member of your team that you view as more expendable) must approach the volcanic vents quite closely and poke into the gas stream a long tube connected through a valve to a sampling reservoir. The reservoir was first pumped down to a respectable vacuum, and when the sampling geologist opens the valve, some of the gas stream is sucked into the reservoir. The valve is then closed, and the gas sample is rushed to a laboratory equipped to analyze it. (Speed is required so the gases do not have much chance to react with one another, or with the walls of the reservoir, and change their compositions.) Gloves, protective suit, and gas masks are fashionable (or, if you want to stay on good terms with your insurance agent, required) wear for the sampling geologist, and it is prudent to pay some attention to what the volcano is doing, to minimize the risk that the geologist will be incorporated into the products of the vent. However, this investigation is really quite safe, in the opinions of most team leaders.

The results will be reported by the analytical laboratory as a general description of the gases found, with estimates of tons per day emitted by the volcano that was surveyed. Because of uncertainties in the whole process, these estimates are a bit up in the air. Proportions of magmatic gases are likely to be more useful to you as guides to the state of the volcano than are the estimates of the total amounts released by the volcano.

AR: Ages of Rocks from a Volcano

Aim: To use the distributions of ages of prehistoric eruptions as guides to future volcanic activity.

Background: Volcanoes often fall into an apparent pattern of activity, with some tendency to repeat whatever they have been accustomed to do in the past. Of course, it is easy to over-emphasize the regularity of these patterns, both because of wishful thinking and because of the human tendency to "see" regular patterns even when they really do not exist. Still, it is useful to know about the past activity of a volcano when one is trying to guess what it will do. Even in a region that has been settled for a long time by humans accustomed to keeping written records, the time scales on which we can view historic volcanic activity are short compared to the time scales on which many volcanoes pass through their "life cycles." Earth scientists have invented many ways of determining ages of volcanic materials, such as lavas, to try to deal with difficulties posed by the comparatively brief human perspective. Techniques based on the decay of radioactive isotopes in rocks or minerals, or on other features such as luminescence of minerals, can be applied to rocks collected from volcanoes in your areas.

Method: You have some experts in determining ages of volcanic rock on your team, or available to you because they are part of the staff of the Age-Measurements Laboratory of Project Central, so you don't have to know a lot about the details of the methods they use. They will work on any volcano to which you direct their attentions, and will report to you the ages they have determined that lie between 1,000 and 9,000 years B.P. ("B.P." means "before the present"). In many respects, it is easier to determine ages of older rocks, but those ages are of little use to you in predicting volcanic activity within the immediate future, so the Age-Measurements Laboratory has concentrated (quite successfully!) on refining techniques for determining ages of young volcanic rocks.

In the past, when you have asked the experts on your team or at Project Central what the reported ages mean, they began arguing with one another, and it is many hours before you get any answers that make any sense, if ever. Consequently, when you see a plot of ages determined for a specific volcano, it is probably better to try to figure out for yourself what they might indicate. Look for the following kinds of features: Do the ages seem to clump in some way, or are they scattered in time without any recognizable pattern? Are there lots of young ages, close to 1,000 to 3,000 or so years B.P.? Or has most of the prehistoric activity of your volcano occurred longer ago? How many rocks were found to have ages in the interval between 9,000 and 1,000 year B.P.? Looking at the data in this way is not likely to give you conclusive answers about what that volcano will do, but it may help.

NOTES

III. Troubleshooting

Refer to this section if your new Volcanoes program does not work properly.

The program never starts, or dies soon after starting.

- Check the instructions for getting started. Try them again, following all the steps exactly.
- Check to see that you have the diskette in disk drive #1, and that this drive is in slot #6.
- Make sure you have all the equipment necessary to run this program, and that it is properly connected. See the front page of this booklet for a list of necessary equipment.
- Make sure your disk drive is working properly. Try another diskette which you know to be good. If it also does not start properly, stop the computer immediately, and disconnect the drive. Do not use the drive again until it is checked, or it may damage other diskettes.

Your disk becomes damaged.

Given normal use, it should not be possible to damage your diskette. Should your diskette become damaged, please send us the diskette together with a short description of the problem. The Software Guild℠ will replace your disk promptly, per provisions in the warranty.

Other problems.

If you have problems with your program, please contact the dealer where you purchased the software. They have the experience and service network to assist you.

The objective of the Software Guild is to provide the highest quality software products available. In order to improve our products wherever possible, we are happy to receive comments, criticism or praise. Write to us at:

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